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DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
JAMES BOYD, DIRECTOR

INFORMATION CIRCULAR

# PROCEDURE USED IN FIGHTING AND SEALING A FIRE IN AN OHIO COAL MINE AND RECOVERY OF THE MINE BY AIR-LOCKING METHODS

BY

G. W. GROVE, F. E. GRIFFITH, AND H. R. BURDELSKY

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# PROCEDURE USED IN FIGHTING AND SEALING A FIRE IN AN OHIO COAL MINE AND RECOVERY OF THE MINE BY AIR-LOCKING METHODS[1]

By G. W. Grove,[2] F. E. Griffith,[3] and H. R. Burdelsky[4]

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## INTRODUCTION

The work of using a system of air locks in unsealing a mine in Ohio following a fire probably was one of the outstanding jobs of its kind in a medium-thick coal bed.

The fire in this mine, thought to have been of electrical origin, was discovered at about 1:30 a.m. on December 11, 1941. Forty-four men were working in the affected section at the time; 5 escaped unassisted, and 37, who had barricaded themselves, were rescued. The bodies of two men, who had succumbed after breathing fumes given off by the fire, were brought part way out of the mine before it became necessary to seal the mine.

Direct attempts to extinguish the fire with water were abandoned when hazardous amounts of carbon monoxide, methane, and other inflammable gases were detected in return air passing through the main haulageway and escapeway of the mine.

The mine was completely sealed on the surface at about 8 p.m. on December 12, 1941, with the two bodies remaining in the mine. Sixteen days after the mine had been sealed, the two bodies were recovered. This was accomplished by air-locking through a partitioned-off stairs compartment of a ventilation shaft. This work was done under adverse barometric and atmospheric conditions.

A method for collecting representative air samples from the immediate fire area was used successfully by utilizing a vacuum pump on about 10,000 feet of existing water line that had been broken near the fire area.

The immediate fire region was sealed and confined to a relatively small area; the remainder of the mine was recovered, and operations were resumed February 9, 1942, or 59 days from the time of sealing the mine on the surface. This recovery was made by air-locking the main entries inby from the shaft and No. 2 right-face entries.

The distance between air locks averaged about 500 feet, and as each new set of seal stoppings and air locks was completed, the old or outby seals were taken out and the area between was ventilated. In ventilating this area, it was often necessary to use line curtains to direct the air into dead-end places.

The fire region was recovered on October 17, 1943, 22 months after the fire had been sealed, and most of the equipment that was in the area was removed and reconditioned.



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Recovery operations, for the most part, were conducted on the basis of three 8-hour shifts a day. Three mine rescue crews on each shift were used during the major part of the recovery work. A crew consisted of five regular oxygen breathing-apparatus men, and during most of the work the crews were accompanied by a State or a Bureau of Mines representative. A number of other men were used during the air-locking operations to handle supplies, clean falls, and construct stoppings outby the sealed area.

The outstanding feature of this mine-recovery work was that approximately 1,550 man-hours were spent in hazardous atmospheres behind the fire seals while wearing self-contained oxygen breathing apparatus. This work was carried on under definitely hazardous conditions, and, with the exception of slight temporary illness of two men, one of whom was wearing oxygen breathing apparatus, recovery operations were carried on without personal injury.

This information circular is not intended to serve as a guide for future operations of this kind, for each undertaking presents its own problems; the information in the circular shows, however, that this kind of work, if properly planned and organized, can be carried on safely and effectively.

## SYSTEM OF MINING AND VENTILATION

A panel room-and-pillar method of mining is used, and pillars are not extracted. The main entries are driven on the butt cleats and are in sets of six. Cross or panel entries driven in sets of four are turned at 2,400-foot intervals. Room entries are driven in sets of three on the butt cleats, and rooms on 38-foot centers, driven 28 feet wide and about 300 feet deep, are developed on the face cleats.

At the time of this fire, the mine was opened by four vertical shafts and one slope. The principal operations of recovering the mine were carried on through shaft "A", the location of which is indicated in figure 2.

Air circulation was induced by a propeller-blade fan operated blowing. The fan was sending into the mine about 100,000 cubic feet of air a minute at a 4-inch water-gage pressure. The fan is offset from the shaft, and the shaft is divided by a brick curtain wall; one compartment serves for downcasting air and as an escapeway. Stairs were provided in the escapeway.

The mine is rated gassy by the Ohio Division of Mines, and all foremen are certified by this Division.

## RECOVERY OF A MINE BY AIR LOCKING

Air locking may be defined as a method by which entrance can be made into an area of a mine from which the normal atmospheric air is excluded by airtight seals with doors in each seal to form an air lock for ingress and egress.



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The seals are intended to prevent normal air from entering the sealed fire region and increasing the oxygen confined within the sealed area. If oxygen is prevented from entering a sealed fire area, the oxygen within the region will be reduced gradually by the fire, coal, timbering, etc., and in time will be lowered enough so combustion will cease, thereby extinguishing the fire.

Air locking into a sealed area of a mine is begun by erecting two stoppings in an entry or slope, each provided with a tight-fitting door. These stoppings should be spaced only sufficiently far apart to accommodate the longest boards or other material likely to be taken into the sealed area. A mine rescue team equipped with self-contained oxygen breathing apparatus and the materials needed to complete the assigned work enters through the first door, and then closes it. The second door is then opened; the rescue team enters the sealed region and closes the second door and then proceeds in vitiated air to carry out the assigned work, which may be locating suitable places for erection of new seals and new air locks at a point several hundred feet inby the present ones, or to carry the necessary materials and build new seal stoppings. After the new seals have been erected and made tight by plastering, the area outby is opened and ventilated. The method used in reventilating the recovered areas in this mine is shown in figure 1. Sketches "A" and "B" on figure 1 show the method employed in ventilating dead-end places. These operations are carried forward step by step toward the seat of the fire. The air locks may be only a few hundred feet apart, depending on conditions encountered, such as height of coal, amount of fallen material, waterpools, etc.

Rescue teams should not be permitted to travel or work more than 1,000 feet inby the air lock or fresh-air base. Rescue crews should be permitted to construct air-lock seals as far as 1,000 feet from the fresh air base only when the conditions are ideal; when travelways are straight, level, unobstructed, free from smoke, falls, or deep pools of water, and 5 feet or more in height; and when a reserve rescue crew is at the fresh-air base ready to act immediately in case of trouble to any of the advance crew.

Because of the extremely hazardous conditions usually confronted during air-locking operations, it is desirable that rescue teams limit the distance between air-lock seals to about 500 feet.

Air-locking operations should never be undertaken until the oxygen content of the air in the region behind the seals has been reduced to at least 5 percent, particularly in a gassy mine. The lower the oxygen content is within the sealed area before starting the air-locking recovery work, the less likelihood of interruption once the work is begun. Owing to unavoidable infiltration of normal air, the oxygen content of the atmosphere behind the seals will increase. Explosive mixtures of methane can be formed with as little as 12.1 percent oxygen, hydrogen with 5 percent oxygen, and carbon monoxide with 5.9 percent oxygen. Other flammable gases driven off or distilled from coal when it is heated require a lower percentage of oxygen than methane. Therefore, careful analysis of the atmosphere collected from behind the seals and interpretation of these analyses by experienced persons



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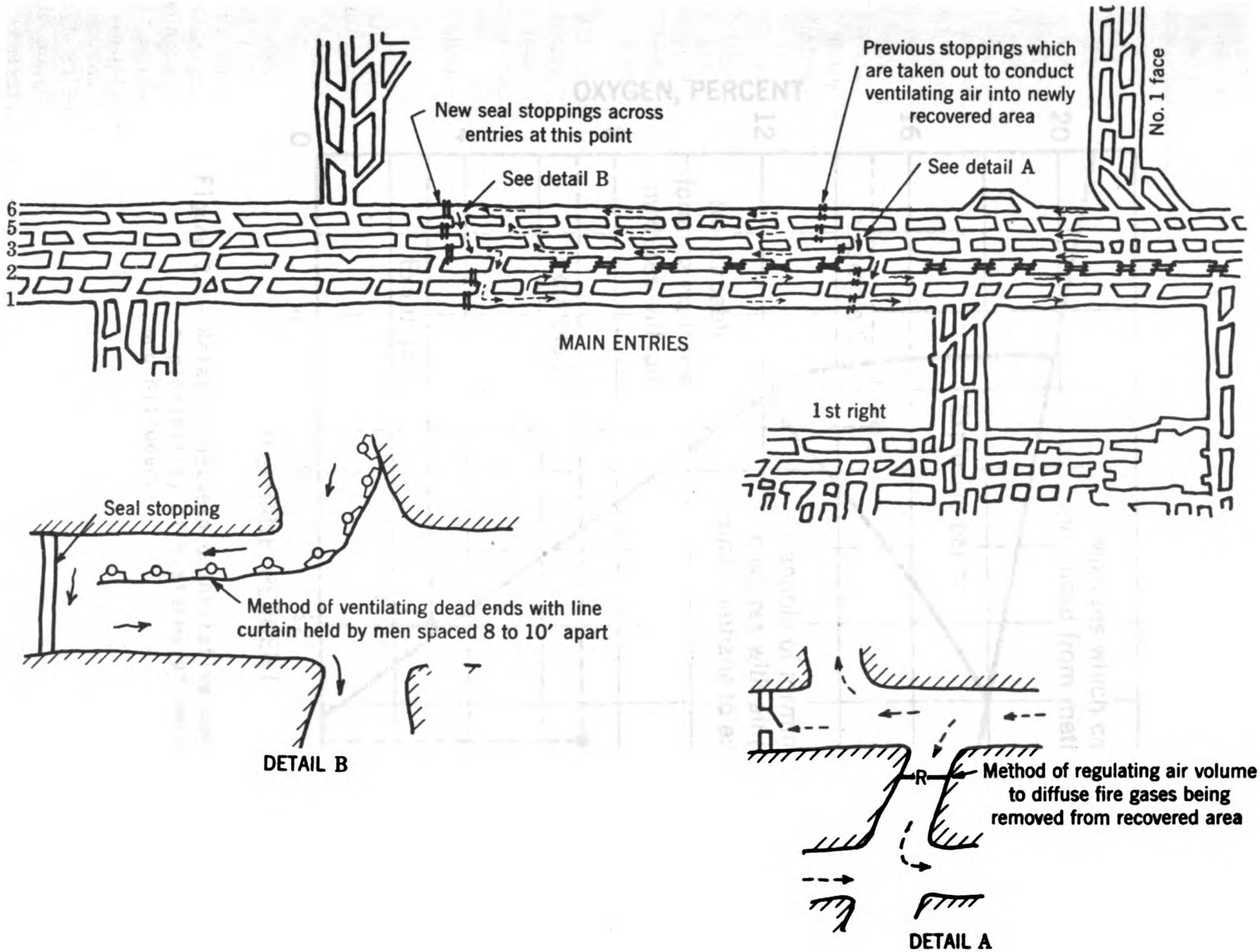
New seal stoppings across entries at this point
See detail B
Previous stoppings which are taken out to conduct ventilating air into newly recovered area
See detail A
No. 1 face
6
5
3
2
1
MAIN ENTRIES
1st right
Seal stopping
Method of ventilating dead ends with line curtain held by men spaced 8 to 10′ apart
DETAIL B
R
Method of regulating air volume to diffuse fire gases being removed from recovered area
DETAIL A

Figure 1. - Typical air-locking operation and ventilation of a newly recovered area.

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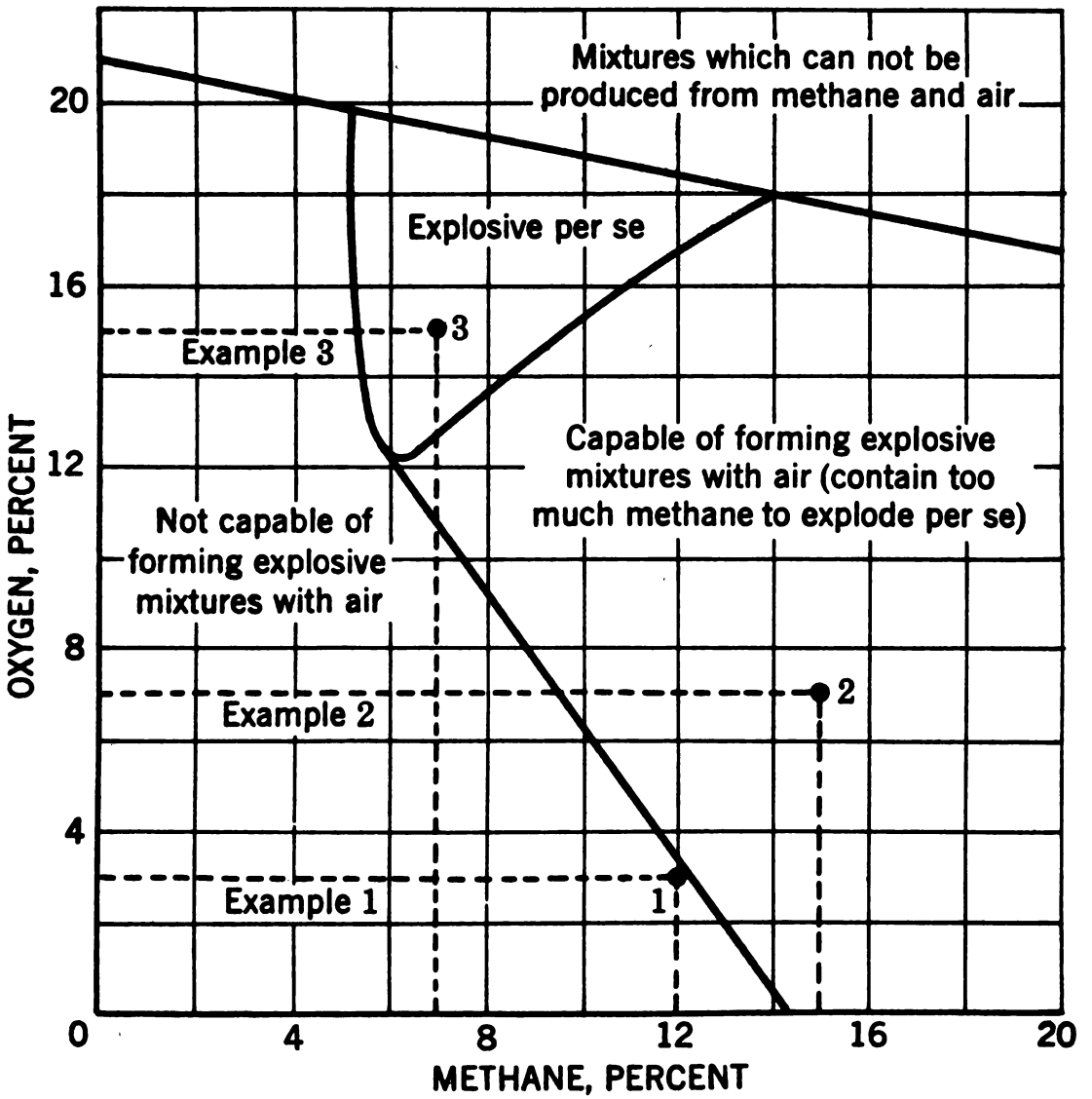


Figure 2. - Relation between quantitative composition and explosibility of mixtures of methane, oxygen and nitrogen.

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are essential adjuncts to the procedure before air-locking operations can be carried on safely. Moreover, oxygen breathing-apparatus wearers should be selected and trained carefully, the work should be well planned and organized, and all materials needed should be at hand before any of the mine recovery is begun.

If combinations of different flammable gases that can be made explosive when admixed with air are present behind fire seals, the oxygen content in the atmosphere in the area should be reduced to 2 percent or less before air-locking operations are attempted. Moreover, all work carried on behind the seals should be discontinued if the oxygen should exceed 5 percent. If the sum of flammable gases other than methane does not exceed 1 percent of the total volume of samples collected from behind the seals, then changing the value of oxygen necessary to form an explosive mixture as compared with methane alone is insignificant. Therefore, in this case, the total combustible gases in the sample may be considered on the basis of methane alone. If methane is the only significant combustible gas present behind the seals, all work in this area should be discontinued when the oxygen reaches a value of about 10 percent.

A graph (fig. 2) showing the relationship between quantitative composition and explosibility of mixtures of methane, air, and nitrogen is often used by Bureau of Mines engineers to plot the methane and oxygen found by analyses and determine, within sufficiently close limits, whether the mixture is explosive or whether it can or cannot be made to form an explosive mixture by addition of air.

Example 1: If an air sample is analyzed and indicates, by analysis, that 12 percent methane and 3 percent oxygen are present, by plotting this analysis on the graph, as shown in figure 2 by dotted lines marked Example 1, it will be noted that the lines intersect each other at a point marked 1. Any point falling within this area is not capable of forming an explosive mixture with air.

Example 2: If it is found by analysis that a sample of air contains 7 percent oxygen and 15 percent methane, it is found (fig. 2) that, plotting in accordance with dotted lines marked Example 2, the point marked 2 falls within the area that is capable of forming an explosive mixture upon addition of normal air. The sample in this case contains too much methane to explode by itself if brought in contact with a source of ignition.

Example 3: If a sample contains 15 percent oxygen and 7 percent methane, it will be found, by plotting in accordance with dotted lines marked Example 3, that the intersecting point 3 falls within the area of mixtures that will explode if ignited without the addition of air or of methane.

It can be seen from the examples cited that the use of such a graph provides a relatively quick means of determining the explosibility of methane-air mixtures.



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## SEALING AND RECOVERY OF MINE FIRE BY AIR LOCKING

### Details of the Fire and Rescue

The procedures described in this paper were those employed in coping with a serious fire that started at 1:30 a.m. on December 11, 1941, from an electrical source and was believed to have originated in the left entry of 7 butt left off 2 right face entries inby No. 19 room. The cause of the fire is not definitely known, but it is thought that it was due to a mining-machine trailing cable near 20 room, 7 left entry. Apparently, a failure caused the electric conductors to heat and ignite the rubber insulation of the cable.

Forty-four men were working in the 7 left section at the time of the fire. Of this number, 37 men barricaded themselves in the bleeder entries inby 7 left and were rescued by the superintendent and other mine officials at 5:35 a.m. on the day of the fire. The barricade stoppings were constructed of several thicknesses of brattice cloth and involved about 60 feet of entry. About 3 hours were spent behind the barricade before the men were rescued. (For details see fig. 3.)

Four men escaped from the section, unassisted. They made their escape through 7 left, and these four, together with a belt-loading-head operator, made their way out to the main west entries through the adjoining face entries. Two of the 44 men working in the section died from breathing the deadly fumes. With the aid of sufficient ventilation to partly clear the smoke, and by the use of self-rescuer gas masks, the bodies of the two men were recovered and taken from the affected section of the mine. The fire burned unabated for several hours, owing to the time spent rescuing the barricaded men, removing the bodies, and laying pipe lines for fire-hose connections. At the conclusion of this work, the fire was attacked by direct methods.

### Method of Attacking Fire

The fire was attacked directly with water and rock dust. This method continued for many hours, and it appeared the fire was under control. However, an exploration trip by two men wearing universal-type gas masks revealed that the fire had spread to No. 2 entry of the group of three, on which a rubber belt conveyor was installed; the lubricant from around belt rollers and the coal spillage along this entry were burning. Double-canvas stoppings between entries at this point had burned completely.

About 9:15 a.m. on December 12, word was received from the chief mine inspector that a dangerous concentration of carbon monoxide and methane gas was found in the main return airway which, in this mine at the time of the fire, was the haulageway. The electric-power circuits to the mine were opened, and the men fighting the fire were ordered to come to the surface.

A conference of those directing, supervising, and assisting with the work was held, and it was decided that because conditions in the mine were



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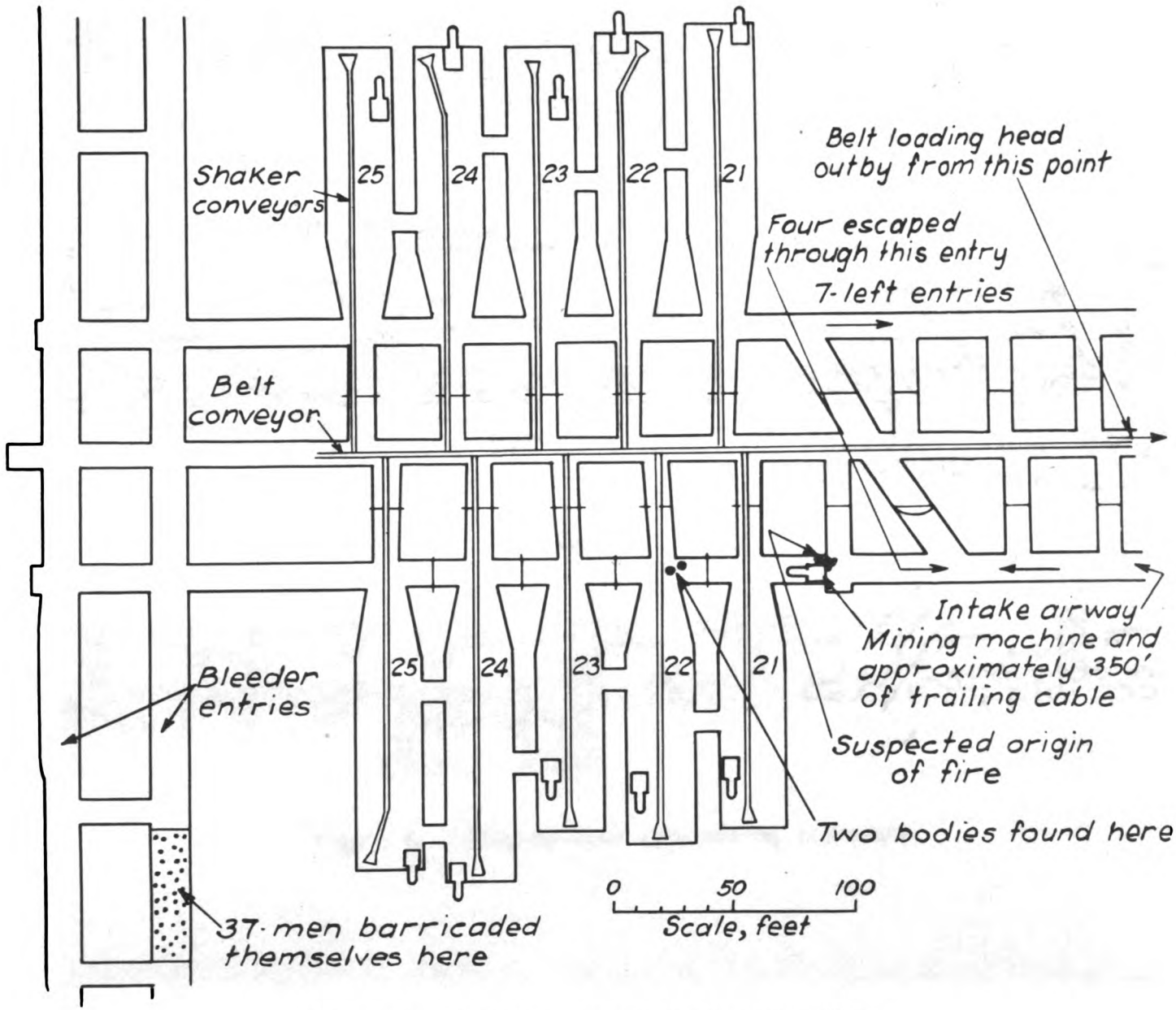


**Figure 3. - Location of barricade and bodies.**

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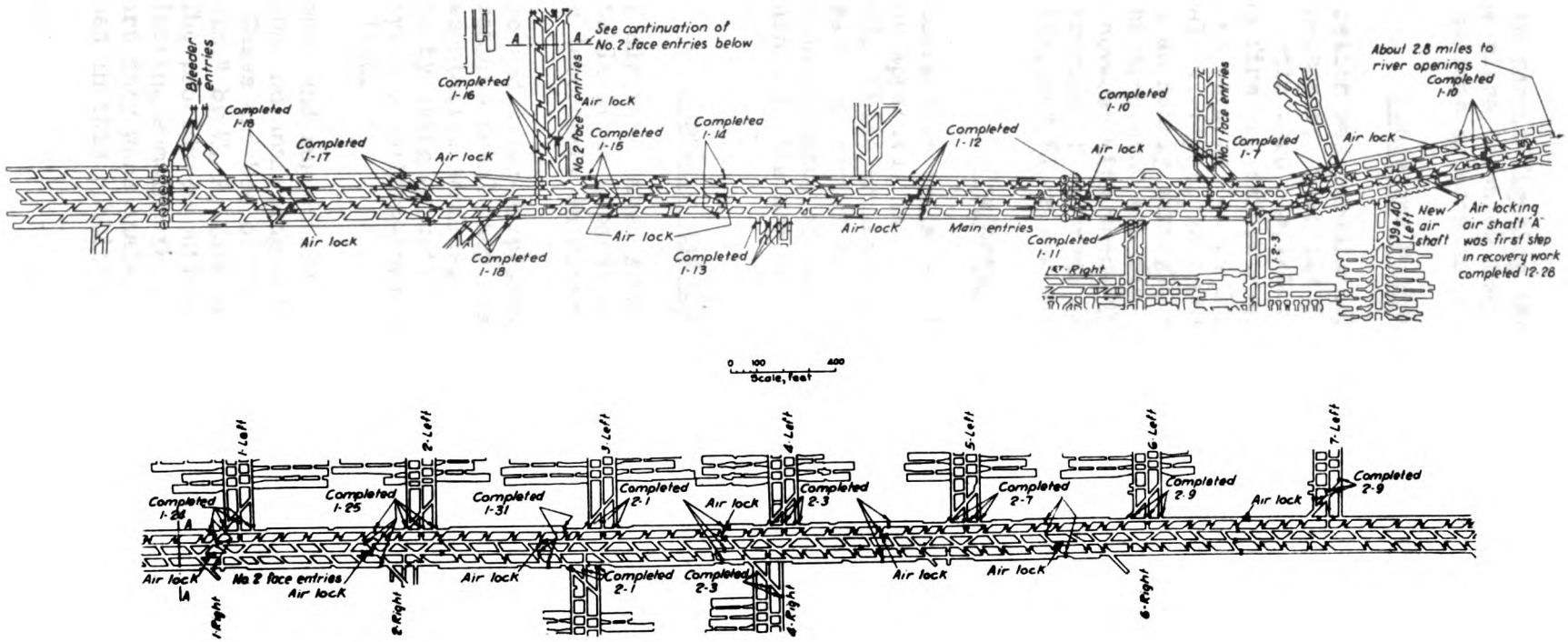


**Figure 4. - Step-by-step air-locking procedure.**

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too hazardous to permit fighting the fire directly or to recover the two bodies from the place to which they had been moved, the mine would be sealed at the surface as soon as possible.

## Procedure Followed in Sealing Mine

An organization was immediately established, and preparations were made to obtain the necessary materials for temporarily sealing all the surface openings. The seals were completed at 8 p.m. on December 12, 1941, 42-1/2 hours after the fire was discovered. After the necessary provisions were made, air samples were collected from the sealed area. Some of the seals were not entirely airtight, as constructed, and others developed leaks; these were made as nearly airtight as feasible by plastering. Except for the steel fan housing over the fan shaft, the seals enclosing the mine consisted of wood covered with wood-fiber plaster. Permanent stoppings, subsequently constructed of concrete blocks laid in cement mortar, were hitched in the roof, ribs, and floor and were made airtight by plastering.

## Preparation for Unsealing

It was necessary to train men in the use and care of self-contained oxygen breathing apparatus and to assemble other equipment before recovery work was started. While training these men, a small one-story frame surface building was constructed at air shaft "A" (see fig. 4) for the storing, recharging, and maintenance of the oxygen breathing apparatus. A total of 60 men were trained in the use and care of the self-contained oxygen breathing apparatus.

## Sampling and Analysis of Atmosphere

Samples of air were taken from behind the seals at intervals and analyzed on a portable Orsat apparatus. An occasional sample was sent to the Bureau of Mines laboratory in Pittsburgh, Pa., for check analysis.

Vacuum-tube and water-displacement air-sample containers were used for confining the samples until they were analyzed, and two methods were employed to obtain representative samples. One method was to draw air from the sealed area of the mine by using a suction pump; and in the second case, samples were collected by oxygen breathing-apparatus crews who entered the sealed area through an air lock.

For reference and suggestions concerning proper procedures to be followed in sampling and analyzing mine gases, Miners' Circular 34, entitled "Sampling Mine Gases and Use of the Bureau of Mines Portable Orsat Apparatus in their Analysis," by W. P. Yant and L. B. Berger, contains much valuable information. The procedures outlined in this publication were followed closely in collecting samples from behind the fire seals at this mine and for the most part they were analyzed on a portable Orsat apparatus similar to that described in this publication.



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## Preparation for Air Locking

At a conference held on the afternoon and evening of December 27, 1941, it was decided to recover the bodies and a major part of the mine by a system of air locks. Careful consideration was given to the results of analytical reports of samples collected (see table 1), and, finding them favorable, the plan of procedure was explained to all present who were to participate in the work, and it was decided to begin air-locking operations at 8 a.m. on Sunday, December 28, 1941. A wooden tunnel equipped with doors was built against a sheet-steel fan building at air shaft "A" to serve as an air lock. (See fig. 4 for location of air shaft "A" and step-by-step air-locking procedure.)

At about 7 a.m. on December 28, 1941, the water gage was 7 inches below the atmospheric pressure, and it rose to 6 inches below atmospheric pressure at 8 a.m. The seal on the door of the sheet-steel fan building that entered the escapeway compartment of air shaft "A" was broken. When this door was opened, the wooden air lock previously erected for rescue crews to enter the mine began collapsing because of the high differential pressure between the atmospheric and the mine pressures. The air-lock entrance had been designed for a neutral or slightly positive mine pressure. The wooden air lock was repaired and reinforced, but the water gage, instead of rising toward a neutral pressure, as it had on previous occasions, remained at 6 inches. It was decided, however, to carry on the first step of the plan, which was to send an apparatus crew to close a door 30 feet inby the shaft bottom. Closing this door would seal the escapeway compartment of the shaft away from the remainder of the mine.

It was decided that as an appreciable volume of air had entered the mine when the air lock partly collapsed, the trip down the shaft might be made in fresh air. A party consisting of two Bureau of Mines men, one State mine inspector, and one company official was organized. This party, equipped with a flame safety lamp, a carbon-monoxide detector, a batteryless mine rescue telephone, and such tools as would be necessary to accomplish the job, entered the air lock. The party was supported by a reserve oxygen breathing-apparatus crew consisting of State inspectors and Bureau of Mines personnel. The trip was made to the bottom of the 110-foot shaft, but some difficulty was experienced. The mine foreman, while closing small holes in a brick curtain wall, was partly overcome from breathing low-oxygen atmosphere seeping into the stairway from the ventilation compartment. It was therefore necessary to return to the surface before the door at the bottom of the shaft could be closed and sealed.

A short time after the fresh-air party returned to the surface, an oxygen breathing-apparatus crew was sent into the mine and completed closing and sealing the door near the bottom of the shaft. The escapeway stair compartment of the shaft was then ventilated by using a small blower fan to blow fresh air into the compartment through "vent tubing" that was extended to the bottom of the shaft.

An air lock was built near the bottom of the shaft, which involved much work and ingenuity. Because of the great height, timbers, and other obstacles,



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a wooden rectangular air-lock house about 7 by 8 by 15 feet was built against the shaft-bottom stopping to serve as an air lock when entering the sealed mine. The two bodies that had been left in the mine when it was sealed were recovered through this air lock by a mine rescue crew wearing oxygen breathing apparatus and were brought to the surface at 5 p.m. on December 28, 1941, 15 days and 21 hours after the mine had been sealed. At the time the bodies were being recovered, an air sample was collected on the haulageway about 25 feet inby the air lock.

While this sample was being analyzed on a portable Orsat apparatus, an oxygen breathing-apparatus crew made an exploration trip inby on the main entries to find suitable sites for subsequent seals and to collect an air sample in the vicinity of south entries off the main entries. At the conclusion of the exploration trip, word was received from the surface that the air sample collected 25 feet inby the air lock on the main west haulageway showed the following constituents: Carbon dioxide, 1.21 percent; oxygen, 11.51 percent; and methane, 10.4 percent. After receiving this information, it was decided to do no further work inby the air lock until the sample of air collected near the left entries by the oxygen breathing-apparatus crew had been analyzed. This sample showed the following: Carbon dioxide, 1 percent; oxygen, 15.15 percent; and methane, 2.86 percent.

A conference was held following verification of the favorable analytical results. Most of the conferees were versed in the technique of rescue and recovery work and interpretation of air and gas analyses. As methane gas has an explosive range of 5 to 15 percent when mixed with air and will explode when the oxygen content exceeds 12.1 percent, it was decided that the recovery operations should be stopped until some means of obtaining representative samples from the immediate fire area were found.

After much discussion of ways that might be used to collect such representative air samples, a suitable method for accomplishing this was found. This consisted of collecting the samples through a water pipe line about 10,000 feet long that was already installed in the mine. This involved making a short trip into the sealed area to close a valve on a branch pipe line and make it suitable for collecting the air samples. After the valve had been closed, an oil-well suction pump was installed on the surface and was used to draw air from the pipe line that extended into the immediate fire area. The water line had been broken near the fire area by the fire-fighting crew. Analyses of air samples taken from this pipe line were invaluable in determining atmospheric conditions in the vicinity of the fire.

## RECOVERY OPERATIONS

Recovery of the mine workings began at 4 p.m. on January 5, 1942. The oxygen breathing-apparatus crews, coal company officials, and State and Bureau of Mines representatives were divided into three shifts. The first shift was to start work at 4 p.m. and work until 12 midnight, the second shift from 12 midnight to 8 a.m., and the third shift from 8 a.m. to 4 p.m. The first group, consisting of two mine rescue crews equipped with self-contained oxygen breathing apparatus, accompanied by representatives from



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the coal company, the State, and the Bureau of Mines, proceeded to the fresh-air base already established near the bottom of the air shaft "A". Oxygen breathing-apparatus crew No. 2, equipped with a portable (battery-less-type) telephone, made an exploration trip through the air lock to collect air samples, select suitable sites at which to erect new seals, and to measure the entries where the new seal stoppings were to be constructed. This was done, and the crew returned to the fresh-air base. The following is an example of a work log showing work accomplished from January 5 to 10, 1942; this was made at the time the work was being carried on:

No. 1 crew entered the air lock at bottom of the air shaft "A" at 6:35 p.m., removed a fall that was obstructing the haulageway, set posts, and started to erect stoppings. The crew returned to the fresh-air base at 7:40 p.m.

No. 2 crew entered the air lock at the bottom of the air shaft "A" at 8 p.m., continued the construction of stoppings not completed by crew No. 1, and returned to the fresh-air base at 9:22 p.m.

No. 1 crew entered air lock at the bottom of the air shaft "A" at 10:30 p.m., completed No. 39 left stopping, and built No. 40 left stopping except for a few boards on one side. The crew returned to fresh-air base at 12 midnight. (See fig. 4 for location of seal stoppings.)

Shift from 12 midnight to 8 a.m. on January 6

No. 2 crew entered air lock at 1:15 a.m., completed the stopping in No. 1 main entry, and returned to fresh-air base at bottom of shaft at 2:15 a.m.

No. 5 crew entered air lock at 2:20 a.m., carried supplies, and returned to fresh-air base at 2:50 a.m. Oxygen supply low on the oxygen breathing apparatus worn by one member of the crew.

No. 2 crew entered air lock at 4:15 a.m., started building a stopping in No. 3 main entry, and located a suitable place for a stopping in No. 2 main. The crew returned to fresh-air base at bottom of shaft at 5:30 a.m.

No. 5 crew entered air lock at 5:35 a.m., knocked hole through crosscut stopping, completed stopping No. 3 main entry, and returned to fresh-air base at 6:05 a.m. All crews out at 6:15 a.m.

Shift from 8 a.m. to 4 p.m.

No. 6 crew entered air lock at 9:10 a.m., cleaned fall, and returned to fresh-air base at 10:20 a.m.



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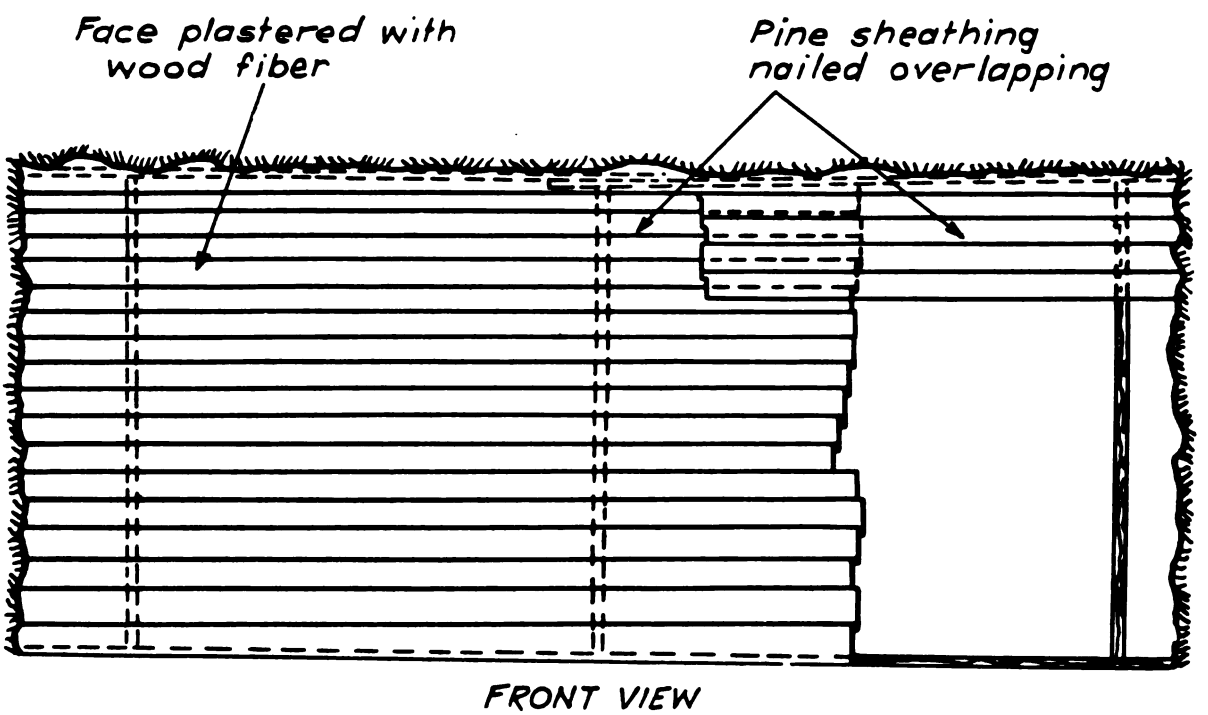


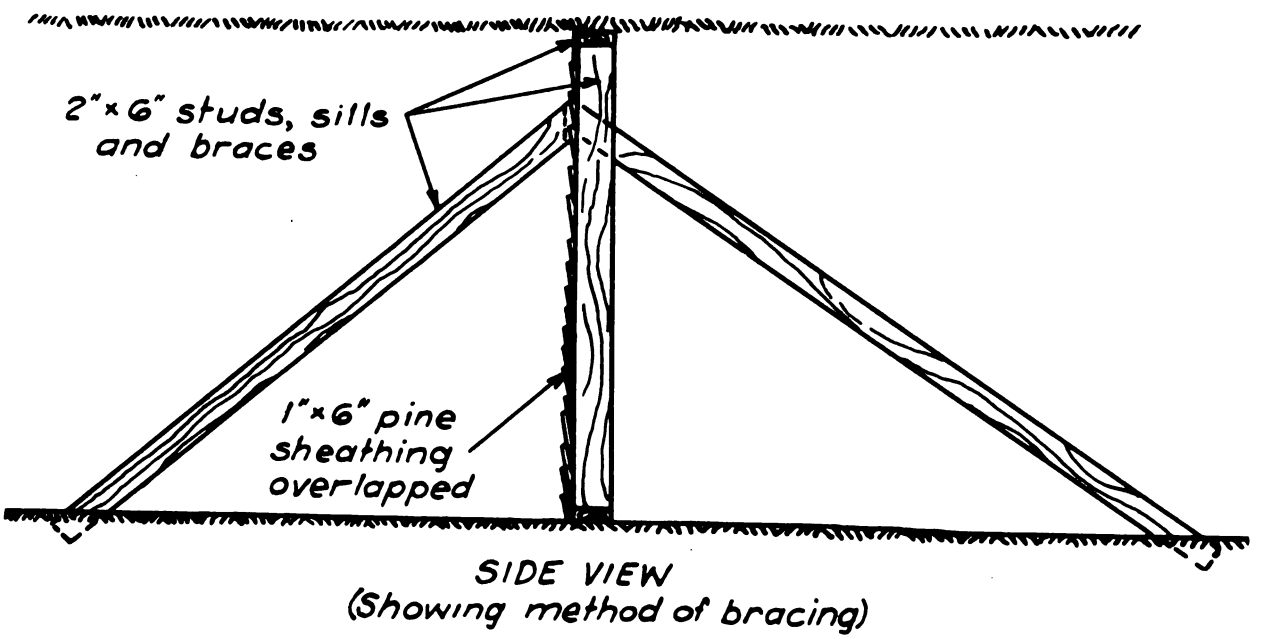


Figure 5. - Method of constructing stoppings.

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No. 3 crew entered air lock at 10:30 a.m., completed No. 1 main entry stopping, and returned to fresh-air base at 12:15 p.m.

No. 3 crew entered air lock at 2 p.m., took measurements of Nos. 4 and 5 main entries, and returned to fresh-air base at 3:45 p.m.

Shift from 4 p.m. to 12 midnight

No. 1 crew entered air lock at 5:05 p.m., loaded material for construction of Nos. 4 and 5 main entry stoppings, completed seal stopping on No. 4 entry, and returned to fresh-air base at 6:35 p.m.

No. 4 crew entered air lock at 6:40 p.m., erected stopping at No. 5 entry, and returned to fresh-air base at 8:40 p.m.

An inspection was made of all stoppings, and it was recommended that all stoppings be braced before they were plastered. (Fig. 5 shows construction details of seal stopping and bracing.)

No. 1 crew entered air lock at 10 p.m. A supply of wood-fiber plaster was distributed to the seal stoppings, and the team plastered the seal stopping on No. 5 entry and returned to fresh-air base at 11:50 p.m. Air samples were collected on No. 4 and No. 5 main entries outby new seal stoppings.

Shift from 12 midnight to 8 a.m. on January 7

Nos. 5 and 2 crews cleaned and charged self-contained oxygen breathing apparatus.

No. 5 crew entered air lock at 1:43 a.m. and continued work of plastering stoppings. The crew returned to fresh-air base at 2 a.m.

No. 2 crew entered air lock at 2:05 a.m., plastered and braced No. 4 main entry stopping, and returned to fresh-air base at 3:55 a.m.

No. 2 crew entered air lock at 5:15 a.m., plastered and braced Nos. 3 and 2 main entry stoppings, placed pipe in No. 3 to collect air samples, and returned to fresh-air base at 7 a.m.

No. 3 crew entered air lock at 9:10 a.m., braced and plastered No. 1 main entry stopping, and returned to fresh-air base at 11 a.m.

No. 6 crew entered air lock at 11:05 a.m., completed No. 40 left stopping, and returned to fresh-air base at 12:10 p.m.



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. . No. 3 crew entered air lock at 1:12 p.m., completed No. 39 left stopping, closed door at pump, and returned to fresh-air base at 2:30 p.m.

After the completion of the seven stoppings, indicated in the preceding log, the seals were removed from the surface openings, and the fan was started at a slow speed at 5 p.m. on January 7, 1942. There was a large area to be ventilated outby the newly constructed seals; however, with four openings being used as outlets, the fire gases cleared rapidly from this portion of the mine.

An air lock was constructed and completed on the main haulageway on January 10, 1942. The next step in the recovery plan required the construction of 17 stoppings, some of which were to be constructed 950 feet from the air lock. A small truck was taken through the air lock to haul material for constructing the stoppings. The air-locking operations continued to, and including, February 9, 1942, at which time all of the working section of the mine had been recovered, excepting 7 left off 2 north; a relatively small portion of the mine remained sealed. (See fig. 6.)

## REMOVING GAS FROM NEWLY RECOVERED AREAS

After the completion of a set of new seals while working through the air lock, the outby seals were removed. The recovered area was then ventilated. The method employed in doing this is shown in figure 1. While these areas were being ventilated, smoking was prohibited in nearby buildings on the surface, and men were placed near surface openings to prevent unauthorized persons from passing while the gases were being removed from the newly recovered area. After each new area was recovered, all of it was thoroughly rock-dusted before subsequent air-locking operations began.

## ATTEMPTS TO RECOVER 7 LEFT SECTION

The portion of the mine inby 7 left off 2 north entries remained sealed until July 4, 1942, 5-1/2 months from the inception of the fire. Study of the analyses of air collected from the fire area indicated that recovery operations could be begun. (See table 1.) An air lock was constructed on the No. 1 entry of this group of three 7 left entries, and an attempt was made to explore the fire area on July 9, 1943.

High falls of roof material were encountered by the oxygen breathing-apparatus crew, and further effort to recover the area was temporarily discontinued. The seals enclosing the fire area were patrolled daily; masonry stoppings were erected outby the plastered wooden seals; and air samples were collected at intervals from the remaining sealed area.

The fire area in 7 left section remained sealed until October 10, 1943, or a period of about 22 months after the fire began, before any further effort was made to recover it. In the meantime, three room entries were driven from three face entries, a territory newly developed since the beginning of the fire. One of these room entries was connected through to a pair of bleeder entries. An exploration trip was made into the fire area,



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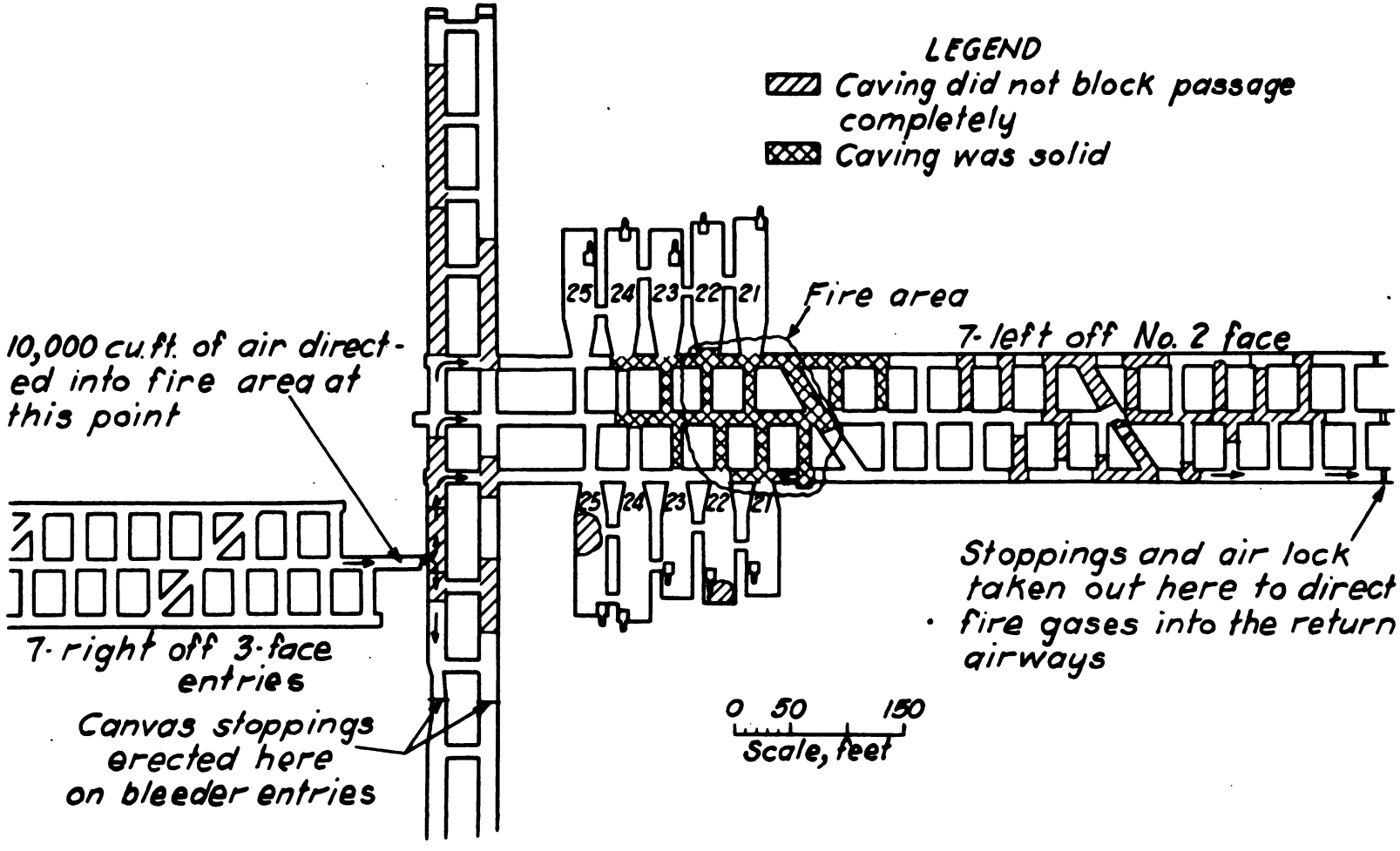
LEGEND
Caving did not block passage completely
Caving was solid
25 24 23 22 21
Fire area
7- left off No. 2 face
10,000 cu.ft. of air directed into fire area at this point
25 24 23 22 21
Stoppings and air lock taken out here to direct fire gases into the return airways
7- right off 3-face entries
Canvas stoppings erected here on bleeder entries
0 50 150
Scale, feet

Figure 6. - Plan of 7-left working section and 7-right entries off 3-face driven to connect with the sealed section for ventilation purposes.

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using self-contained oxygen breathing apparatus, through an air lock built a short distance outby this new opening. The fire area was found to be cool, and no fog zone was encountered. The analyses of two air samples collected in the fire area showed 3.9 percent carbon dioxide, 5.3 and 5.2 percent oxygen, less than 0.005 percent carbon monoxide, and 11.4 and 11.0 percent methane, respectively.

TABLE 1. - Analyses of air samples collected from the fire area through a water pipe line

| Date | Time | $CO_2$ | $O_2$ | CO | $CH_4$ |
|---|---|---|---|---|---|
| 1/3/42 ..... | 4:00 p.m. | 1.29 | 7.33 | 0.00 | 8.81 |
| 1/3/42 ..... | 6:00 p.m. | 2.91 | 4.48 | 0.22 | 10.02 |
| 1/3/42 ..... | 8:00 p.m. | 2.92 | 4.04 | 0.34 | 10.78 |
| 1/3/42 ..... | 10:00 p.m. | 3.08 | 4.18 | 0.22 | 11.45 |
| 1/4/42 ..... | 8:00 a.m. | 2.80 | 3.40 | 0.00 | 10.40 |
| 1/4/42 ..... | 1:00 p.m. | 2.60 | 3.60 | 0.00 | 10.30 |
| 1/4/42 ..... | 6:00 p.m. | 2.96 | 3.46 | 0.00 | 11.24 |
| 1/4/42 ..... | 10:00 p.m. | 2.73 | 3.58 | 0.00 | 11.24 |
| 1/5/42 ..... | 3:00 a.m. | 2.80 | 3.80 | 0.00 | 10.00 |
| 1/5/42 ..... | 7:00 a.m. | 2.80 | 3.80 | 0.00 | 10.40 |
| 1/5/42 ..... | 11:00 a.m. | 3.00 | 3.80 | 0.00 | 10.00 |
| 1/5/42 ..... | 4:00 p.m. | 3.16 | 4.06 | 0.00 | 23.50 |
| 1/6/42 ..... | 1:00 a.m. | 2.90 | 3.90 | 0.00 | 11.20 |
| 1/6/42 ..... | 6:00 a.m. | 2.30 | 4.00 | 0.00 | 10.40 |
| 1/6/42 ..... | 6:00 p.m. | 2.67 | 3.78 | 0.00 | 10.91 |
| 1/7/42 ..... | 9:00 a.m. | 2.70 | 3.90 | 0.00 | 11.90 |
| 1/7/42 ..... | 11:00 p.m. | 2.60 | 4.20 | 0.00 | 11.30 |
| 1/8/42 ..... | 8:00 a.m. | 2.50 | 5.20 | 0.00 | 9.10 |
| 1/9/42 ..... | 6:00 a.m. | 2.40 | 3.50 | 0.00 | 12.90 |

The analyses of the samples and the conditions found during the exploration indicated that it was favorable to open and ventilate the area; it was decided to do this on October 17.

Before taking the seals out and ventilating the area on October 17, another exploration trip was made through an air lock from the 7 left 2 north side. Conditions were found to be similar to those of the previous exploration. The seals were then taken out of the 7 left 2 face side, and the air was turned into the area through the air locks on 3 face side. About 3 hours were required to ventilate the immediate fire area, after which it was inspected. Large roof falls were found on all of the 7 left entries opposite 21, 22, 23, and 24 rooms. (For details see fig. 6.) The fallen material was loaded into mine cars and taken out of the mine. This material contained much coke and burned limestone.

It should be noted that as the mine was recovered and ventilated all the main and secondary haulageways were put on air coming directly from the outside. Prior to the fire these entries were ventilated with air returning from the working faces.



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## PHASES OF THE RECOVERY PROCEDURE

The first step in recovering the mine and the two bodies was the establishment of a fresh-air base near the bottom of the air shaft "A". This involved air-locking into the stairs compartment of the shaft. There is always a certain risk taken by men protected by oxygen breathing apparatus when working in deadly atmospheres. The risk is greater when the travelway is by stairs, ladders, or steep pitches. Every known precaution was taken to safeguard these men during the first step of recovery as well as during subsequent steps. This first step in the recovery procedure was started and completed on December 28, or 16 days after the mine was sealed. It consisted of establishing a fresh-air base near the bottom of air shaft "A", recovering the two bodies, and making an exploration trip of several hundred feet inby on the haulage and parallel entries.

The second step was the construction of stoppings on the main west entries inby air shaft "A", which began on January 5 and was completed on January 7, a period of 3 days. This step required the construction of seven wooden stoppings, which were braced and covered with wood-fiber plaster. An air lock was built in fresh air on January 8 outby the new fire seal on No. 3 main entry.

The third step required the erection of 17 stoppings, which was started on January 9 and completed on January 11, a period of 3 days. An air lock was constructed January 12, 1942, outby the new fire seal on No. 3 main entry. After the outby seals were knocked out, it was necessary to make a change in the ventilation system before the newly recovered area could be ventilated. Following this, an exploration trip was made in the area by company officials and State and Bureau representatives, and a flame safety lamp and a carbon-monoxide detector were used to test the atmosphere. The condition found in the area indicated that it was safe to continue the recovery work.

This method of recovery, using air locks to keep the fire sealed, reventilating the recovered area, and then inspecting them, continued to February 9, when the major part of the mine was recovered.

### Water-Gage and Barometer Readings

From December 17, 1941, to January 7, 1942, water-gage readings and outside barometric-pressure readings were taken. These readings, together with calculated inside barometric pressures, indicated a wide variation in barometric pressure, causing appreciable changes in the static mine-air pressure. On January 2, 1942, the water gage showed a pressure of 9.2 inches below atmospheric pressure within the mine, and on December 21, 1941, it showed a pressure of 6.7 inches above atmospheric pressure, or a spread of 15.9 inches. This was the maximum spread in water gage from highest positive to lowest negative pressures (above and below atmospheric pressure) during the time the mine was sealed.

The method used for calculating the inside barometric pressure was as follows:



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29.92 inches of Hg at sea level = 14.7 pounds per square inch or barometer.
1-inch water gage = 5.2 pounds per square foot, or
1-inch water gage = 0.0361 pound per square inch.

29.92 : 14.7 :: x : 0.0361 = 0.073 conversion. This conversion figure, 0.073, times the water-gage pressure equals the difference to be added to or subtracted from the outside barometer to give the inside barometric pressure.

The following examples are given to show the calculations made to obtain an approximate inside barometric pressure reading:

Example 1: In table 2, sample No. 5, the water-gage reading, taken at about the same time this sample was collected, was 4.3 inches above atmospheric pressure, and the outside barometric pressure at this time was 29.69 inches of mercury. Using the conversion figure of 0.073, then 29.69 minus 0.3139 (4.3 times 0.073) gives inside barometric pressure approximating 29.38 inches of mercury.

Example 2: In the case of sample No. 12, listed in table 2, the water gage was 5.45 inches below atmospheric pressure at 2 p.m. on January 1, 1942, and the outside barometric pressure was 28.99. Thus, using the conversion figure 0.073 times 5.45 plus 28.99, which approximates 29.38 inches of mercury as being the inside barometric pressure.

TABLE 2. - Samples collected at shaft "A"

| No. | Date | Time | Percent | | | | Inches water gage* | Barometer outside | Barometer inside calculated |
|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $O_2$ | CO | $CH_4$ | | | |
| 1 | 12/23/41 | 2:45 a.m. | 0.42 | 19.54 | 0.21 | 0.26 | 0.3 - | 29.34 | 29.36 |
| 2 | 12/23/41 | 2:00 p.m. | 1.22 | 10.55 | 0.81 | 1.60 | 3.2 - | 29.04 | 29.27 |
| 3 | 12/24/41 | 2:35 a.m. | 1.00 | 7.00 | 1.20 | 2.09 | 6.0 - | 28.70 | 29.13 |
| 4 | 12/24/41 | 3:00 p.m. | 1.15 | 3.69 | 0.92 | 3.47 | 1.0 - | 28.75 | 28.82 |
| 5 | 12/29/41 | 6:45 p.m. | 1.01 | 11.60 | 0.40 | 3.22 | 4.3 + | 29.69 | 29.38 |
| 6 | 12/29/41 | 10:45 p.m. | 0.93 | 14.27 | 0.00 | 3.70 | 4.1 + | 29.70 | 29.41 |
| 7 | 12/30/41 | 2:45 a.m. | 0.93 | 12.07 | 0.23 | 2.36 | 3.6 + | 29.67 | 29.41 |
| 8 | 12/30/41 | 3:00 p.m. | 1.20 | 11.10 | 0.00 | 5.54 | 1.25+ | 29.54 | 29.45 |
| 9 | 12/31/41 | 3:00 a.m. | 1.80 | 10.95 | 0.00 | 6.07 | 0.5 + | 29.46 | 29.42 |
| 10 | 12/31/41 | 3:00 p.m. | 1.82 | 9.92 | 0.30 | 7.44 | 0.5 + | 29.46 | 29.42 |
| 11 | 1/ 1/42 | 2:00 a.m. | 1.40 | 9.09 | 0.00 | 6.18 | 0.20- | 29.38 | 29.39 |
| 12 | 1/ 1/42 | 2:00 p.m. | 1.70 | 9.00 | 0.20 | 4.50 | 5.45- | 28.99 | 29.38 |
| 13 | 1/ 2/42 | 1:00 a.m. | 1.90 | 8.60 | 0.00 | 6.90 | 9.2 - | 28.66 | 29.33 |
| 14 | 1/ 2/42 | 2:00 a.m. | 2.00 | 8.50 | 0.00 | 6.80 | 7.25- | 28.71 | 29.23 |
| 15 | 1/ 2/42 | 2:00 p.m. | 2.00 | 8.49 | 0.00 | 7.51 | 0.5 + | 29.18 | 29.15 |
| 16 | 1/ 3/42 | 2:52 a.m. | 1.80 | 10.30 | 0.00 | 5.60 | 3.6 + | 29.37 | 29.11 |
| 17 | 1/ 3/42 | 12:30 p.m. | 1.60 | 9.90 | 0.00 | 5.78 | 3.15+ | 29.38 | 29.05 |

*The plus or minus sign following the water-gage reading indicates whether the air pressure in the mine was above or below the atmospheric pressure.



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The advantage of calculating the inside barometric pressure is that any excessive leakage of air into or out of the mine can be detected readily. In order to do this, curves should be plotted of the outside barometric pressure readings, the water-gage readings, and the calculated inside barometric pressure. If a relatively small quantity of air leaks into or out from behind the seals, this would be indicated by a nearly flat inside barometric-pressure curve; if much air leakage occurs, this curve will follow closely the outside barometric curve, and immediate attention should be given to tightening the seals.

## Statistics on Recovery Operations

The principal recovery operations were conducted on the basis of three 8-hour shifts a day. There were two United States Bureau of Mines employees and at least one State mine inspector at the fresh-air base while self-contained oxygen breathing-apparatus crews worked in and around the air-locked area. Two to three mine rescue crews of five men each were used on each shift.

Approximately 18,000 man-hours of labor have been charged by the company to fire fighting and recovery work.

A State or a Bureau of Mines representative wearing a self-contained oxygen breathing apparatus accompanied the apparatus crews during much of the work carried on within the sealed area.

About 34 8-hour working days were required to complete recovery operations. A daily average of 30 mine rescue-team members worked 34 8-hour shifts, or 8,160 man-hours were worked by rescue team members. A daily average of 36 men was employed to supply material, clean haulage roads, construct permanent stoppings, and do other jobs that did not require the use of oxygen breathing apparatus, or about 9,800 man-hours were worked by fresh-air crews. It is noteworthy that approximately 1,550 man-hours were spent behind the fire seals wearing self-contained oxygen breathing apparatus; this work was carried on under low roof and many other unfavorable working and traveling conditions.

It should be especially noted that all of this hazardous work was accomplished without a lost-time accident. No person suffered more than minor temporary ill effect from wearing the self-contained oxygen breathing apparatus or from any other work carried on during the recovery operation. Much credit for this achievement is due to (1) a well-conceived and executed plan of operations, (2) the selection of physically fit oxygen breathing-apparatus men, (3) the thorough training of mine rescue crews, and (4) the use of a batteryless telephone system of communication between the fresh-air base and crews operating inby the air locks. The use of the telephone system had much to do with maintaining good morale among apparatus men and with alleviating the anxiety of those directing the operations.

The use of the telephone during these operations is the second case in which the batteryless mine rescue telephone and life-line assembly developed



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by the Bureau of Mines was used in recovery work following a mine fire. An earlier model of this telephone was used at Kramer, Pa., following two mine explosions in March 1937 that killed nine mine officials. In this case, the use of the batteryless telephone by mine rescue teams was credited with saving two lives and possibly a third. While exploring several hundred feet in advance of fresh air, one team member had serious difficulty with the self-contained oxygen breathing apparatus he was wearing. In their effort to aid this apparatus man, two other members of the five-man rescue team had their nose clips dislodged, breathed the deadly gases surrounding them, and were overcome. The team captain, who was wearing the throat transmitter, advised the fresh-air-base attendant the moment the first member affected experienced trouble, and a reserve crew was sent to the scene and rescued the three men. The affected men were revived by artificial respiration and the administration of oxygen. As the telephone played such an important part in saving these men, in that persons directing the operations were immediately notified of the rescue team's distress, its value in this kind of work was definitely proven. As previously indicated, there were no such mishaps in the work described in this circular.

The recovery work required the building of 113 wood-plastered stoppings and 18 air locks, cleaning falls, knocking out brick and concrete stoppings, and ventilating some of the recovered area by manually holding a line curtain. (See figs. 1 and 4 for details.)

## Type of Stoppings and Miscellaneous Details

The stoppings were constructed mainly of 3/4- by 6-inch pine sheathing and were nailed to 2- by 6-inch frame studding. The sheathing was lapped upward. (See fig. 5.) All of the stoppings were braced and then plastered with "wood fiber.". The stoppings were built by crews wearing self-contained oxygen breathing apparatus. The air locks were built by carpenters working in fresh air.

Brass hammers were used in the construction of stoppings, and bronze-faced sledge hammers were used to knock out brick and tile stoppings.

The track and electric-power conductors were opened at a point outby each air lock to minimize the danger from electric arcs and sparks.

Following ventilation of each air lock, the area was thoroughly rock-dusted by hand and by a rock-dusting machine.

## CONCLUSIONS

In conclusion, it can be stated that the recovery of a mine in which a fire is sealed usually can be accomplished safely by air-locking methods, provided the following points are strictly adhered to:

1. It should be known that the oxygen content of the atmosphere behind the seals is 5 percent or less before any work is started.



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2. It should be known that while the air-locking operations are being carried on, no explosive mixture of gas and air exists behind the seals.

3. All apparatus men should be known to be dependable and to be in good physical condition and well trained and versed in the use, care, and limitations of oxygen breathing apparatus.

4. All oxygen breathing apparatus should be maintained in good condition.

5. The air-locking operations should be well planned before beginning the work.

6. All of the work should be thoroughly organized and coordinated.

7. No attempt should be made to recover a mine or part of a mine by air-locking methods when a fire has existed in the sealed region, unless it is fairly definitely known that the fire has been extinguished.

8. Air-locking procedure may be hazardous in a mine that has overlying cracks or other openings to the surface or to other mines that cannot be reached to make certain as to their tightness to exclude air flow.

9. Mines or parts of mines that have cracked or very thin or otherwise undependable pillars and are sealed, owing to a fire, seldom lend themselves to safe air-locking procedures.



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